The Logical Leap: Induction in Physics by David Harriman. New York: New American Library, 2010. 275 pp., including Index. $16. (paperback). ISBN 9780451230058.

The so-called problem of induction has been with us since David Hume first drew attention to it in the mid-18th century. The problem is that we infer from a number of similar events laws of nature that are universal. We infer the idea of a cue "causing" a billiard ball to move, by observation of many similar events of cues striking billiard balls. Therefore we suppose that the next time we strike a billiard ball with a cue that the ball will move in a similar way. But, says Hume, there is no valid chain of reasoning that can lead to that conclusion (there is no valid Aristotelian syllogism that leads from "some" to "all"). We can introduce an axiom "the future resembles the past" or "nature is uniform in certain regards," but by so doing we are arguing in a circle:

> all inferences from experience suppose . . . that the future will resemble the past, and that similar powers will be conjoined with similar sensible qualities. If there be any suspicion that the course of nature may change, and that the past may be no rule for the future, all experience becomes useless, and can give rise to no inference or conclusion. It is impossible therefore that any arguments from experience can prove this resemblance of the past to the future; since all these arguments are founded on the supposition of that resemblance. (Hume, 1748)

This problem of being unable to get from past observations to some necessarily *true* general principle is known as the "problem of induction."

Induction is contrasted with deduction, which is moving from some true premises inevitably to true conclusions. Aristotle formulated the laws of logic which showed which kind of deductions (syllogisms) lead to correct conclusions, regardless of the actual objects to which the various premises refer. The ubiquitous example is "All As are B; C is A; therefore C is B." Thus "All men are mortal; Socrates is a Man; Therefore Socrates is mortal." The point is that the deduction is *valid* whatever is substituted for A, B, and C. The deduction is not necessarily *true* if the premises are not true: "All men are women; Socrates is a man; therefore Socrates is a woman." There is thus a distinction in Aristotelian logic between the validity of an argument and the truth of the conclusion. Aristotle came to his universal laws of logic by a process of induction. First he examined a great many arguments and arranged them into 192 possible forms, removing the particulars to which the arguments referred. Aristotle then isolated 14 valid syllogisms out of the 192 (later expanded to 19 out of 256) which give true conclusions if the premises are true. Although a syllogism may be valid and true, it does not necessarily get you very far. Take

for example the valid syllogism "no women are immortal; some people are women; therefore some people are mortal." All the valid syllogisms have "all" or "no" in one or the other of the premises. But the only way such premises can be arrived at is by induction or by definition (as in mathematics).

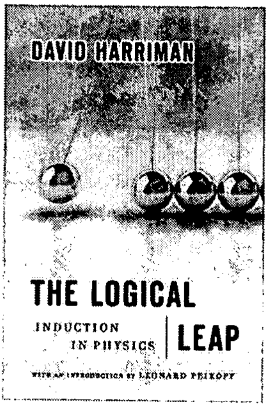
Yet science proceeds from individual experiments and observations to general principles. It is to the problem of when and why the inference from "some" to "all" is legitimate—"in short, how can man determine which generalizations are true (correspond to reality) and which ones false (contradict reality)" (p. 7)—that Harriman sets his mind in *The Logical Leap,* subtitled *Induction in Physics.*

To answer the question, Harriman relies on the Objectivist philosophy of Ayn Rand (1905–1982, author of the novel *Atlas Shrugged* where she describes her philosophy in detail, of other works of fiction, and of numerous philosophical essays). Objectivism takes for granted the validity of sense perception and causality (p. 9). Sense perception is our only contact with reality. From sense perception we find out what exists in the world: tables, chairs, etc. "We form concepts by grasping similarities that make a group of existents stand out against a background of different existents" (p. 10). The concepts formed in this way do not imply that all existents grouped into a concept are the same: Their differences are quantitative. For instance, tables have different surface areas, different heights, and different numbers of legs. "When we form a concept, our mental process consists in retaining the characteristics but omitting their differing measurements"(p. 10).

Concepts are hierarchical. "The meaning of first-level concepts can be made clear simply by pointing to instances" (p. 12). For higher-level concepts we need definitions which must be empirical statements that specify the distinguishing characteristics and condense our knowledge of them. A concept however cannot be equated with its definition:

> The concept 'temperature' had the same meaning for Galileo and Einstein, i.e. both men referred to the same physical property. The difference is only that Einstein knew much more about this property; he understood its relation to heat, to motion, and to the fundamental nature of matter. (p. 13)

Generalizations are also hierarchical, and all generalizations ultimately depend on first-level generalizations: "all generalizations—first level and higher—are statements of causal connection. . . . there is nothing to make any generalization true except some form of causal relationship" (p. 21). Thus, contrary to Hume, we perceive causation directly in the case of the cue and the billiard ball, and in the case of high-level generalizations we discover causes by experiment. We do not discover causes by simply counting regularities or finding correlations.



The above is a (condensed) version of Rand's theory of concepts. The so-called problem of induction relies on prior concepts. "Deduction takes for granted the process of conceptualization. Induction is the conceptualizing process itself in action" (p. 35). The process of making higher-level concepts requires thought and is therefore not infallible. In fact it is quite difficult.

As an example of correct induction, Harriman cites Benjamin Franklin's famous experiment with a kite in a thunderstorm which showed that lightening is essentially electricity. Franklin drew on a number of concepts:

> 'electricity', 'discharge', 'conductor', 'insulator', 'Leyden jar'. These concepts were made possible by and represent a wealth of earlier knowledge (which was also discovered by means of experiment). Without this conceptual framework, as we may call it, Franklin could only have stared uncomprehendingly at sparks and shocks. Given such a framework, however, he can at once identify what he is seeing: The kite apparatus is a long conductor, and thus the electrically charged thundercloud causes [the Leyden jar to become charged]. Once Franklin can identify what he is seeing in such terms, his conclusion—the generalization—follows directly. (p. 32)

Harriman then discusses at length the progress of scientific knowledge in astronomy, physics, and chemistry by the "greats" such as Copernicus, Galileo, Kepler, Newton, Lavoisier, Dalton, Maxwell, and Mendeleev and brings out the mechanics of valid induction, though the accounts might be construed as rather Whiggish, wherein the later theory is accepted as correct, the good guys are the ones who got the answer right, and the bad guys are the ones who tried to resist the right answer.

From this survey, Harriman shows when induction is valid and delineates several fallacies which make induction appear invalid:

a) Dropped context: To say Newton's laws are falsified by the development of relativity and quantum mechanics is to drop the context. They are true in the context of the mechanics of ordinary bodies and the motion of planets, in which context the laws were validly induced. (p. 8)

b) Substituting a regularity for a cause: Lavoisier thought that the presence of oxygen in a chemical compound was what made the chemical acidic. This was merely a regularity in those acids he studied and was not found in hydrochloric acid (then known as muriatic acid). (p. 196)

c) Inadequate experimental controls: Galvani thought that the reason a frog's leg placed on a silver plate jerks when touched by a bronze hook was because electricity was stored in the leg. Volta thought the reason was contact of the different metals and the frog was irrelevant for the production of electricity. Galvani and Volta both performed variations of the experiment which 'proved' their point. Davy later showed that the frog's leg provided a salt solution vital for the operation of the silver–bronze battery. (p. 200)

d) 'Cognitive fixation': The physicist Lord Kelvin 'refuted' the up-and-coming science of geology on the grounds that the age of the Earth, according to the then known physics, was too young for the formation of mountains as postulated by the geologists. Kelvin could not see that the facts of geology suggested another energy source apart from gravity, on which he based his calculations. (p. 206)

e) 'Cognitive promiscuity': Pons & Fleischman proclaimed they had been able to obtain the 'cold fusion' of deuterium atoms in a room-temperature electrolysis experiment, "despite weak evidence and a context that makes the idea implausible.... A mind that is open to any 'possibility', regardless of its relation to the total context of knowledge, is a mind detached from reality and therefore closed to knowledge." (p. 207)

f) 'Theory stealing': Accepting a theory as an instrument for research whilst not believing that the theory refers to reality. This was the situation through much of the 19th century when many chemists did not believe that atoms actually exist, whilst still using the theory to guide their research. (p. 220)

In the final chapter, Harriman turns his attention to quantum theory.

> As a mathematical formalism, quantum theory has been enormously successful. It makes quantitative predictions of impressive accuracy for a vast range of phenomena, providing the basis for modern chemistry, condensed matter physics, nuclear physics, and optics. It also made possible some of the greatest technological innovations of the twentieth century, including computers and lasers. Yet as a fundamental theory of physics it is strangely empty. . . . It gives a mathematical recipe for predicting the statistical behavior of particles but fails to provide causal models of subatomic processes. (p. 248)

According to Harriman, the *necessity* of supposing that a single reality exists, that the human mind has a reasonably clear access to it, and that the scientist can explain it, has been surrendered not by reference to experimental facts ("the knowledge gained by experimental discovery of facts can never lead to the denial of knowledge and fact") but by the influence of post-Kantian philosophy,

> an enemy that operated behind the front lines and provided the corrupt framework used to misinterpret facts. By rejecting causality and accepting the unintelligibility of the atomic world, physicists have reduced themselves to mere calculating machines (at best)—and thus they are unable to ask further questions or to integrate their knowledge.

Harriman does not discuss the double-slit experiment, the EPR experiments of Alain Aspect and others, the quantum Zeno effect, quantum computation, and the various other puzzling phenomena in quantum physics. Harriman himself seems to be "theory stealing" here in that he is willing to accept the benefits he lists from quantum theory without subscribing to the theory itself, nor addressing the really puzzling *experimental* facts on which the theory is based. There is no explanation of why quantum mechanics gives such precise answers whilst it does not correspond to reality.

I do not deny that modern physics is in something of a crisis. 96% of the universe as we know it consists of 'dark matter' and 'dark energy' which we have only the vaguest idea about. The two most successful theories we have, quantum mechanics and general relativity, refer to completely different contexts and are deeply incompatible in those areas where perhaps they both apply (such as black holes). The effort to unify these two great theories has stimulated physicists to retreat into metaphysical speculation of great mathematical complexity (string theory) with as yet no hint of an experimental test.

In short, Harriman presents a reasonable theory of how a science can proceed by induction to true theories (provided you read "true" as "true in context" and not "absolute truth"). He shows, following Rand, that the problem of induction depends on prior concepts that had not been examined by Hume and that science is possible (contrary to the pessimistic conclusions of certain philosophers over the centuries). I am skeptical about his insistence that physics must conform to some pre-ordained form (which might be construed as "cognitive fixation"). As Neils Bohr said in response to Einstein's insistence that "God does not play dice with the universe,": "Do not tell God what to do."

"Physics is the most universal of the natural sciences" (p. ix), and Harriman does not address the sciences such as biology, psychology, sociology, which suffer from "physics envy" but rely even more on statistics than quantum mechanics. It is here that his theory of induction might meet even tougher challenges.

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Reference

Hume, D. (1748). *An Enquiry Concerning Human Understanding.* Section IV, Part II.